Les lois de la fatigue étudiées dans les muscles de l'homme.[1] By Prof. ANGELO MOSSO. Travaux de Lab. de Physiol. de Turin, 1889, pp. 149–212. Reale Accad. dei Lincei, Serie 4, Vol. V, 1888. Archiv f. Anat. u. Physiol. 1890, p. 89. Paper read before The Internat. Cong. of Physiol. at Basel, Sept. 1889. Archiv. Ital. de Biol. t. XIII, p. 123.

The apparatus and experiments described in this paper are of great interest. Not only do they open a large field for work, but they unite more closely than has yet been done the nerve-muscle physiology of the lower animals with that of man. In addition to this they show an intimate connection between the fatigue of the central nervous system and that of the muscles. Two new pieces of apparatus are described and many suggestive experiments recorded. The paper is illustrated by 64 plates. The work covers a wide field, viz: 1. Description of the "Ergographe" and "Ponomètre." 2. A comparison of the curves of fatigue of voluntary muscular contractions with those produced by excitation of nerves and muscles. 3. The fatigue of nerve centres. 4. The influence of psychic fatigue on muscular force. 5. Inhibition of voluntary movements by electric excitation of motor nerves. 6. Muscle contractur. 7. Effect of fatigue on muscle elasticity. 8. Influence of a support on the height of muscular contractions.

In the hope of studying on man the laws of fatigue of the muscles, Mosso constructed an apparatus, which he named the "Ergographe." With it he was able to record the mechanical work performed by the flexor muscles of the middle finger, when contracted voluntarily or in response to an induction current applied directly to the muscles or to their nerves.

If a weight were raised with each flexion of the finger, the work done and the corresponding fatigue were recorded. By means of this apparatus he was able to test on men the results which have been obtained heretofore chiefly on frogs, and the lower warm blooded animals.

Each individual gives a characteristic curve of fatigue and this varies with changes in his general condition as well as local alterations.

It was found that human muscles have an excitability and energy peculiar to themselves and that they weary independently of the excitability and energy of the nerve centers. Thus the muscles are seen to be the seat of certain phenomena of fatigue which thus far have been thought to arise in the central nervous system and to belong essentially to it.

The other new apparatus used in these experiments is the "Ponomètre." By it, the weight is released at a certain point. The further unintentional contraction, made without the weight, depends on the amount of nervous energy employed to compel the muscle to raise the weight. The height of these contractions was seen to increase as the muscle tired and Mosso concluded that this was due to the fact that more nervous energy was developed to produce the desired contraction of the fatigued muscle.

Fatigue of nerve centres. With the "Ergographe" one can study the fatigue of the nervous centres, because one can measure the work of which the muscle is capable, when it is stimulated directly or through its nerve, and compare this with the work which can be done voluntarily. It was found by such experiments that more work could be done by electrical stimulation of the nerve than by voluntary contraction of the muscles. This is true in spite of the fact that one can voluntarily

[1] This paper is supplemented by a paper by ARNALDO MAGGIORA. *Les lois de la fatigue étudiées dans les muscles de l'homme.* Reale Accad. dei Lincei, Vol. V, Séance Nov. 4, 1888. Travaux de Lab. de Physiol. de Turin, 1889, p. 213. Many of the experiments described in this paper were made with Maggiora, and Mosso often refers to his work.

lift much heavier weights, and results from the rapid fatigue of the central as compared with the peripheral mechanism. The muscle is still capable of contracting in response to an electric stimulus applied to its nerve long after the voluntary power has ceased.

Influence of psychic fatigue on muscular force. Having found that the central nervous mechanisms fatigue during muscular work, Mosso sought the effect of central fatigue on the force of voluntary muscular contractions. He found that when a man was mentally tired by a severe examination his voluntary power was lessened. Before concluding that this loss of power was due entirely to central fatigue, he tested the muscle with electricity and found that the absolute power of the muscle itself was lessened. That is to say, he found that the muscles are weakened by severe mental work. The source of this weakness was then studied. It seemed more likely that it was due to some change in the blood than to an influence exerted by the brain through the nerves. Two ways suggest themselves by which the effects of fatigue might work through the circulation, viz., 1. A material poisonous for the muscles might be developed in the brain, as a result of the chemical changes accompanying its work, and thence pass into the general circulation. Or 2. The muscles, as less important mechanisms, might cede a part of their nutriment to the nervous substance as is the case in fasting. Experiments showed that the weakness which results from fasting is rapidly recovered from on taking food, while that caused by vigils and by forced marches is recovered from only by repose of the nervous system, i. e. sleep. These facts make it probable that during severe nervous work a material is produced which on entering the circulation acts as a poison and weakens the muscles. To prove this supposition Mosso tried the effect of injecting blood from a tired dog into one that was fresh. He found that it acted as a poison and produced all the signs of fatigue, though injecting the blood of a fresh dog had no such effect. The result of this experiment was a strong argument in favor of the idea that the weakness which results from mental work is due to a poisonous material produced by chemical changes in the brain.

Inhibition of voluntary movements by electricity applied to motor nerves. Mosso corroborated the observations of Schiff and Fick that an interrupted current applied to a motor nerve prevents the voluntary contraction of the corresponding muscles. He found a weak current to have no inhibiting effect, though it produced a slight contractur of the muscles. A strong current causes a tetanus. A medium current inhibits the voluntary contraction and produces a contractur. The current must last at least 1-5 second to have an inhibitory effect. The voluntary power returns immediately on the removal of the current. This inhibition does not seem to be a reflex phenomenon.

Muscle contractur. Mosso studied on men with the "Ergographe" the phenomenon of contractur, with reference to the results of Tiegel, von Frey, Rossbach, Richet, von Kries and Kronecher, gained from experiments on frogs, etc. He irritated the muscles of a man with a tetanizing current of medium strength every two seconds, and saw a series of contractions the record of the first five of which, on account of the contractur, formed steps, each contraction reaching a higher level than the preceding. At the summit there was a contraction lower than the rest, and then the contractur began to diminish and continued to lessen until the record again started from the abscissa. At its height the contractur was so strong that it supported the weight of 500 grms., at a higher level than the first contraction had lifted it. When the contractur began to lessen, the fatigue seemed to begin. The contractions, which were then greater than at the beginning, fell off rapidly. In voluntary contractions the amount of the contractur varies with the person and the way the weight is applied. It may be strong enough to lift 3 kilos.

Though diminishing as the fatigue comes on, it may in certain persons persist to a certain amount even after the fatigued muscle ceases to respond to stimuli. A very short rest is sufficient to restore the contractur. The intensity of the contractur is in relation to the intensity of the electric excitation up to a certain maximum. It is less marked with voluntary contractions than with those produced by electric excitation. It is only well marked with light weights. The adding of a heavy weight for a time, may be followed on return to a light weight by the contractur. Contractur is entirely a muscular phenomenon in spite of the fact that it is seen more marked in persons in an irritable condition. Indeed in experiments on animals it may be observed on curarized muscles. This observation is important as showing that many phenomena accompanying exaggerated excitability are of peripheral origin and independent of the central nervous system. The contractur seems never to occur in certain muscles as of the eyes, and in other muscles only to accompany excessive effort. It seems to be almost an abnormal condition, a symptom characteristic of an alteration of the muscle produced by too great excitation, and hence as a form of fatigue manifested in the muscle as it passes from a state of rest to that of work. It is probable that the first contractions of a fresh muscle differ from those of a fatigued muscle. Maggiora shows that a fatigued muscle is injured more by work than a fresh muscle. The shape of the muscle curve is influenced, not only by the contractur, but by the elasticity of the muscle and many other factors, so that its interpretation is most difficult. Mosso promises another paper on this subject. In spite of apparent contradictions he looks upon the contractur as a phenomenon of fatigue. It is certain that the nervous excitation produces in the muscle other effects than contraction. One recalls Bowditch's "Treppe." Mosso regards the "Treppe" as due to fatigue. It can be prevented by massage, and he thinks it ceases because the muscle by its contractions massages itself. The relation of these questions to the theory of tetanus is most important and it is to be hoped that Prof. Mosso will continue his work in this direction.

Effect of fatigue on elasticity of muscles. In some experiments the elasticity seems diminished by fatigue, in others the results are masked by the continuance of the contractur. The confusion of terminology—contractur, tonicity, elasticity, makes a clear understanding and statement of results a matter of great difficulty.

The influence of a support on the height of the contraction. The curve of fatigue is uninfluenced by having the weight supported at various heights during the work when the muscle is fresh, but if it be weary the partial removal of the weight increases the height of the contraction, i. e., when fresh, the muscle gives a maximal contraction regardless of the weight, but when weary it is aided if the weight be supported at a certain height. W. P. L.

Ueber die kleinsten wahrnehmbaren Gesichtswinkel in den verschiedenen Teilen des Spektrums. W. UHTHOFF. Zeitsch. f. Psychol. Bd. I, H. 3. 1890.

In connection with his studies on the acuteness of vision, Uhthoff has re-determined the smallest angular distance by which two objects must be separated in order to be seen separately, when illuminated with light of different colors. The importance of his determination rests on his having used spectral lights. The visual object was a fine wire net specially made for the purpose in which the intervals between the wires were just equal to the diameter of the wires, i. e., 0.0463 mm. This was seen against the face of a large prism so fixed that its whole surface was presented to the observer illuminated with one monochromatic light. The wire-net was moved backward and forward between the